

AMBULATION INCREASES DECOMPRESSION SICKNESS IN SPACEWALK SIMULATIONS

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INTRODUCTION

Musculoskeletal activity has the potential to both improve and compromise decompression safety. Exercise enhances inert gas elimination during oxygen breathing prior to decompression (prebreathe), but it may also promote bubble nuclei formation (nucleation), which can lead to gas phase separation and bubble growth and increase the risk of decompression sickness (DCS). The timing, pattern and intensity of musculoskeletal activity and the level of tissue supersaturation may be critical to the net effect. Understanding the relationships is important to evaluate exercise prebreathe protocols and quantify decompression risk in gravity and microgravity environments. Data gathered during NASA's Prebreathe Reduction Program (PRP) studies combined oxygen prebreathe and exercise followed by low pressure (4.3 psi; altitude equivalent of 30,300 ft [9,235 m]) microgravity simulation to produce two protocols used by astronauts preparing for extravehicular activity. Both the Phase II/CEVIS (cycle ergometer vibration isolation system) and ISLE (in-suit light exercise) trials eliminated ambulation to more closely simulate the microgravity environment. The CEVIS results (35 male, 10 female) serve as control data for this NASA/Duke study to investigate the influence of ambulation exercise on bubble formation and the subsequent risk of DCS.

METHODS

Four experiments will replicate the CEVIS exercise-enhanced oxygen prebreathe protocol, each with a different exception. The first of these is currently underway. **Experiment 1** – Subjects complete controlled ambulation (walking in place with fixed cadence and step height) during both preflight and at 4.3 psi instead of remaining non-ambulatory throughout. **Experiment 2** – Subjects remain non-ambulatory during the preflight period and ambulatory at 4.3 psi. **Experiment 3** – Subjects ambulate during the preflight period and remain non-ambulatory at 4.3 psi. **Experiment 4** – The order of heavy and light exercise employed in the CEVIS protocol is reversed, with the light exercise occurring first (subjects remain non-ambulatory throughout). Decompression stress is assessed with non-invasive ultrasound during each of 14 epochs of a 4 hour simulated spacewalk at 4.3 psi; aural Doppler is used to monitor bubbles (Spencer grade 0-IV scale) passing through the pulmonary artery, and two-dimensional echocardiographic imaging is used to look for left ventricular gas emboli (LVGE; the presence of which is a test termination criterion). Venous blood is collected at baseline and twice following repressurization to determine if the decompression stress is correlated with microparticles (cell fragments) accumulation. The plan is to test 25-50 subjects in each experiment. Fisher Exact Tests (one-tailed) are used to compare test and control groups. Trials are suspended when the DCS or grade IV VGE observations reach 70% confidence of DCS risk >15% and grade IV VGE risk >20%.

RESULTS

Experiment 1 was concluded with 20 complete trials (15 male, 5 female) since the statistical outcome would not change with five additional trials. The observed DCS was significantly greater in Experiment 1 than in CEVIS trials (4/20 [20%] vs. 0/45 [0%], respectively, $p=0.007$), as was the frequency of peak grade IV VGE (6/21 [29%; including one additional subject that presented grade IV VGE but whose trial was ended before completion when LVGE were observed] vs. 3/45 [7%], respectively, $p=0.024$). Experiment 3 trials are now underway, with 11 trials completed (10 male, 1 female). Preliminary results indicate no difference in observed DCS between Experiment 3 and CEVIS trials (1/11 [9%] vs. 0/45 [0%], respectively, $p=0.196$), or between Experiment 3 and Experiment 1 trials ($p=0.405$). The frequency of peak grade IV VGE in Experiment 3 (2/11 [18%]) did not differ from CEVIS or Experiment 1 trials ($p=0.251$ and $p=0.425$, respectively). Microparticle patterns are widely variable and still under analysis.

DISCUSSION

The results of the Experiment 1 trials support the thesis that decompression stress is increased by ambulation exercise, given the higher incidence of DCS and grade IV VGE when compared to the non-ambulatory PRP CEVIS trials. Experiment 3 trials are incomplete, but suggest that the effect of ambulation during ground level preflight oxygen breathing alone, when subjects are undersaturated with inert gas, may not differ in risk from ambulation at

both preflight and spacesuit pressures, the latter when subjects are supersaturated with inert gas. Further trials are needed to confirm the relative effects of ambulation in undersaturated vs. supersaturated states and to determine whether light exercise facilitates the removal of heavy exercise-induced nucleation (Experiment 4).

ABSTRACT (353 characters)

Musculoskeletal activity may improve or compromise decompression safety. We evaluated ambulation exercise associated with simulated spacewalk. Decompression sickness was higher when ambulation was conducted at both preflight and spacesuit pressures but, tentatively, not when at preflight pressure alone (4/20 and 1/11 vs. 0/45, $p=0.007$ and $p=0.196$; Fisher Exact). Additional trials may further resolve effects.